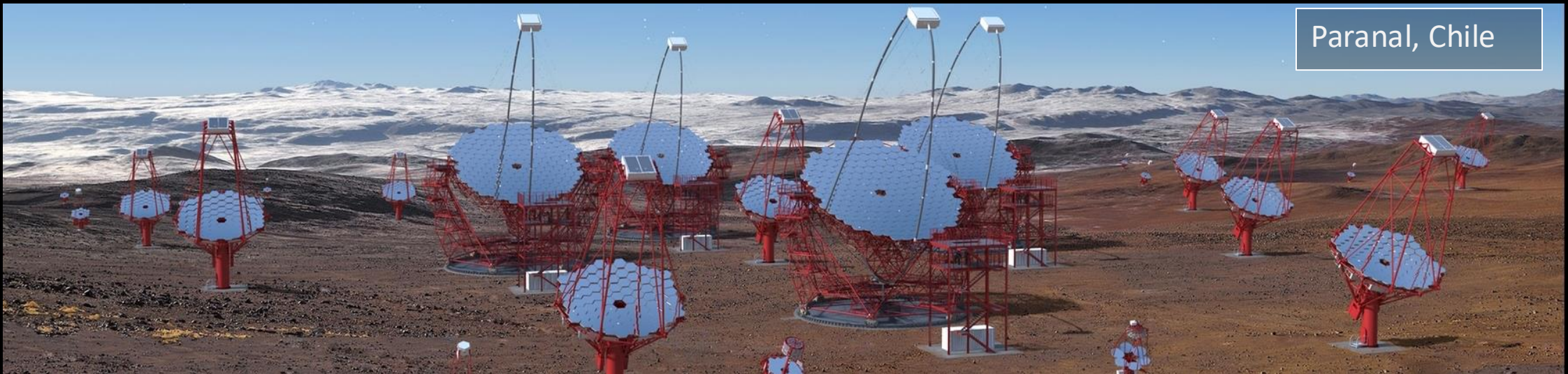
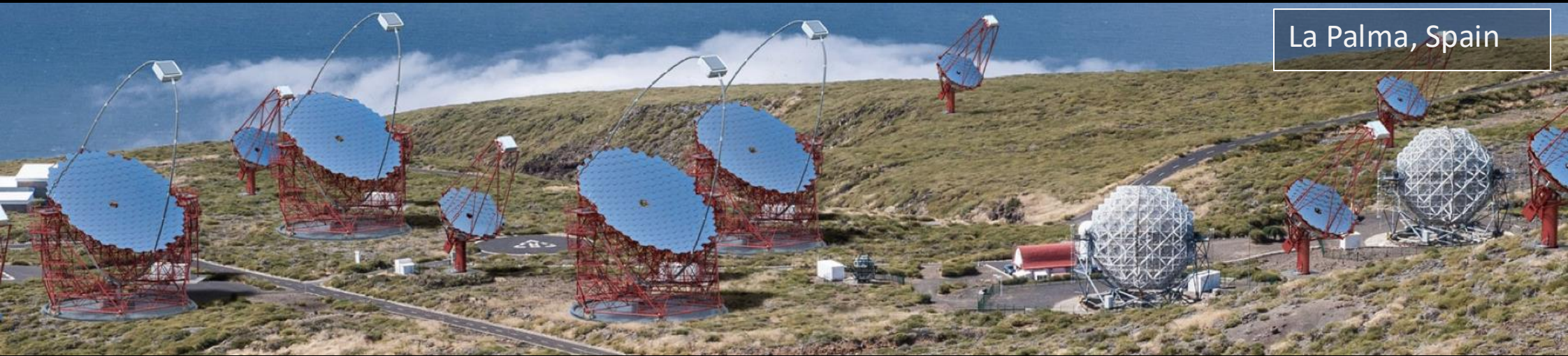


# Status of the LST and Early Science

Masahiro Teshima for the LST Collaboration

*Max Planck Institute for Physics, Munich, Germany  
Institute for Cosmic Ray Research, The University of Tokyo, Japan*

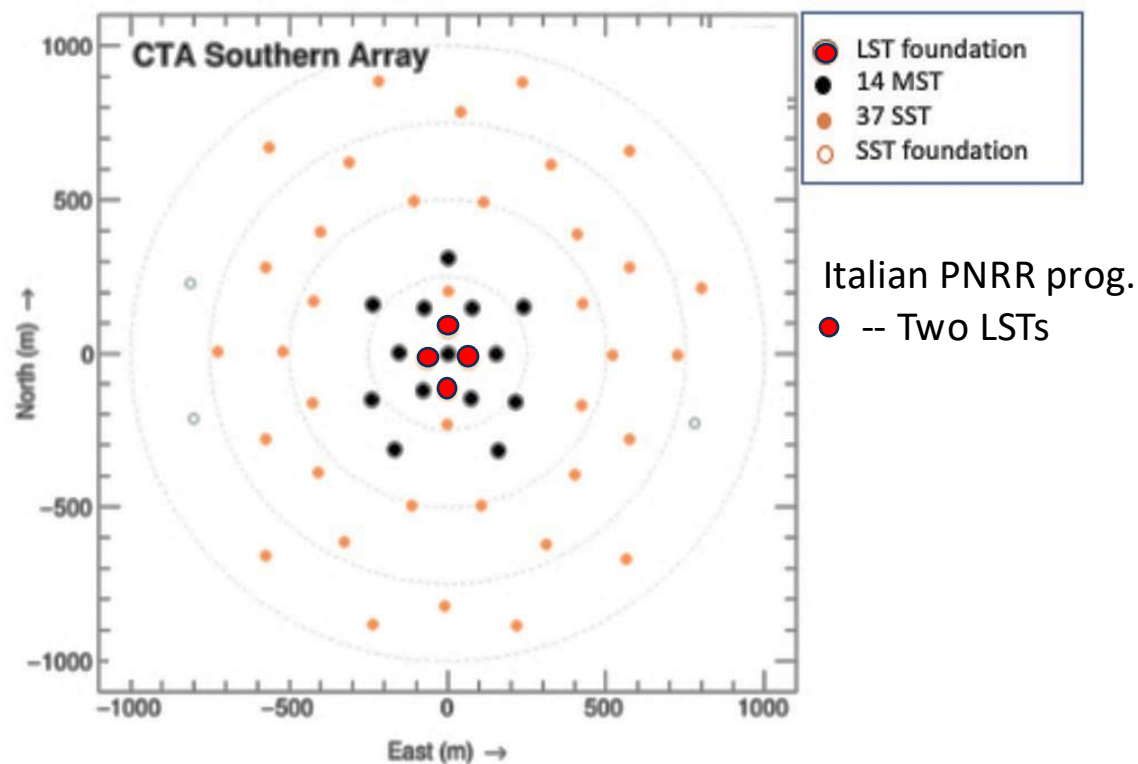
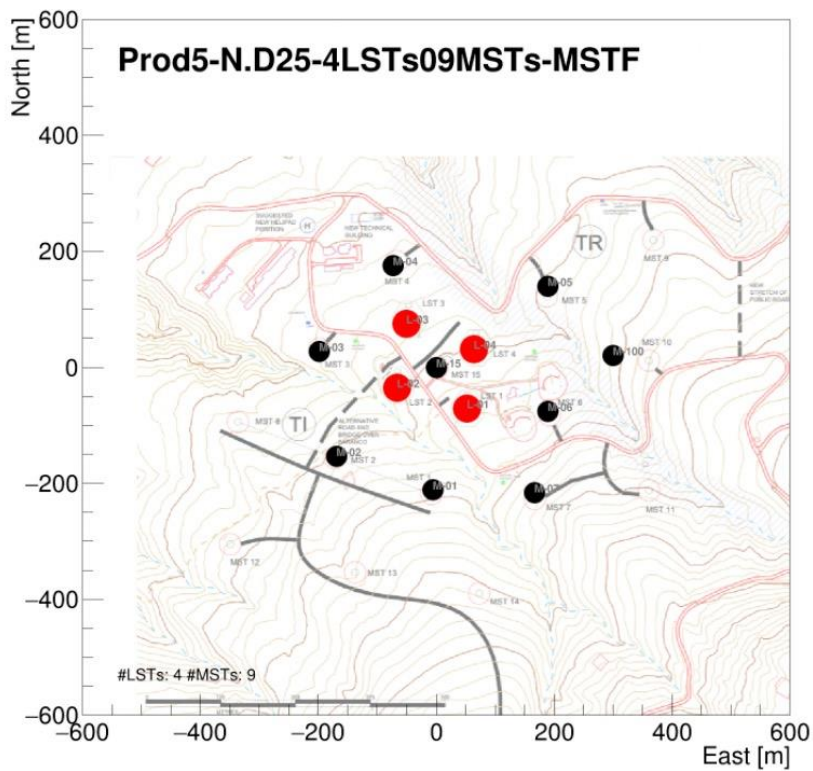
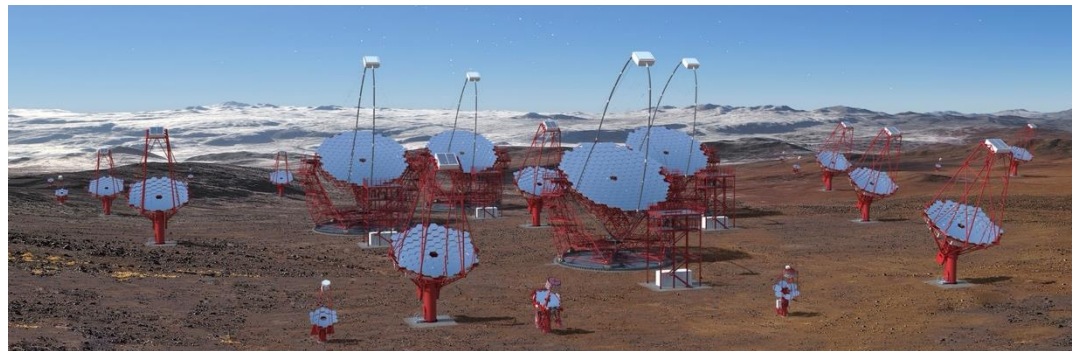


# Alpha Configuration of CTA

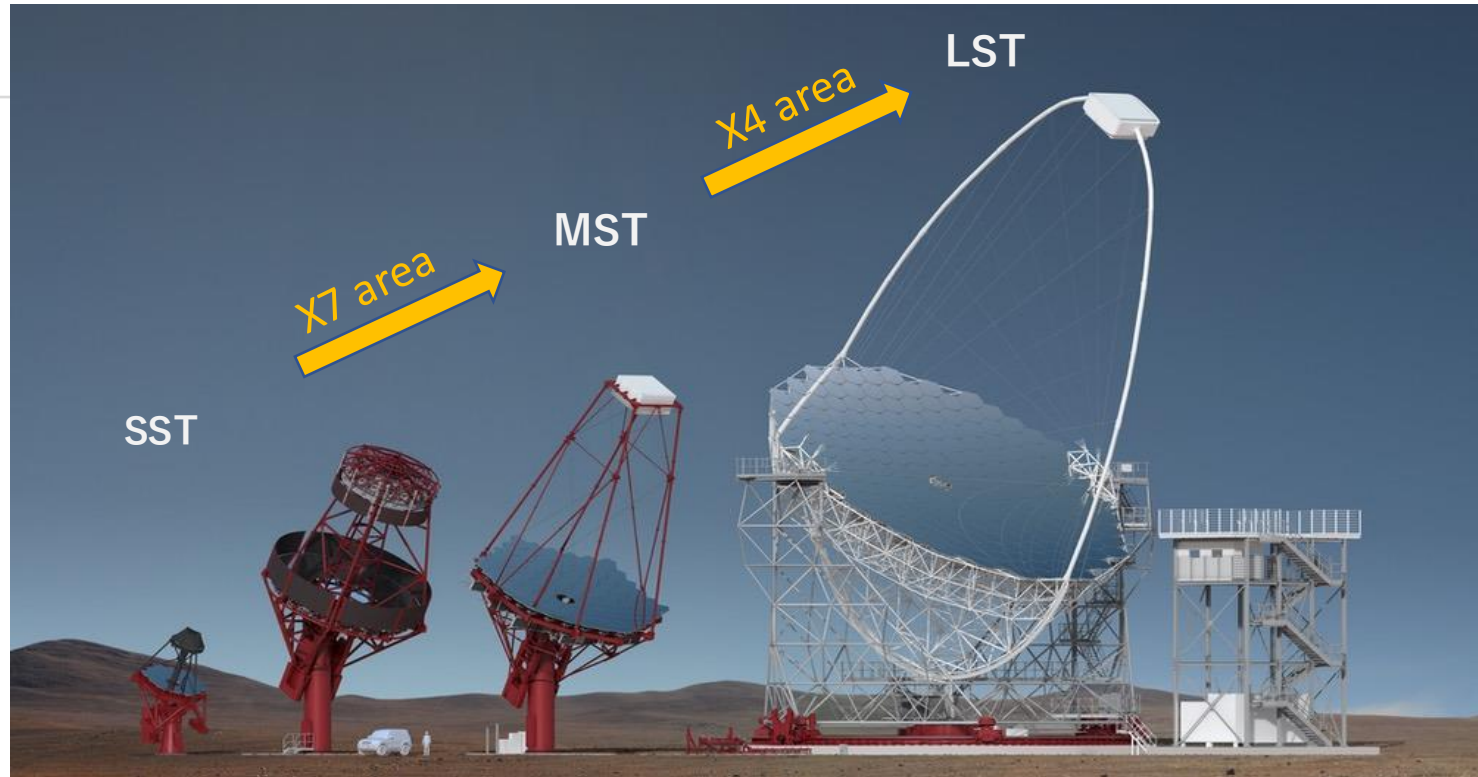
Roque de los Muchachos Observatory  
La Palma, Spain



Paranal, Chile



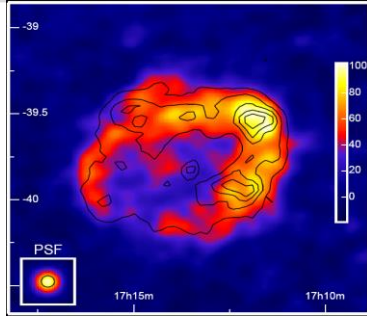
# Telescope Design



Telescope Types	SST	MST	LST
Optics	Schwarzschild-Couder	Davies-Cotton	Parabolic (Isochronous)
FoV and Camera	10.5 deg SiPM	7.5 deg PMT	4.3 deg PMT
Mirror Diameter	4.3m	11.5m	23m
Energy Range	3 TeV - 200 TeV	100GeV - 10TeV	20GeV – 2TeV
Science Targets	Galactic Sources PeVatron (UHE CR)	Galactic Sources Nearby AGNs ( $z < 0.5$ ) Dark Matter	Transient Sources AGNs( $z < 2$ ), GRBs( $z < 4$ ) Dark Matter

# Science of CTA is very wide

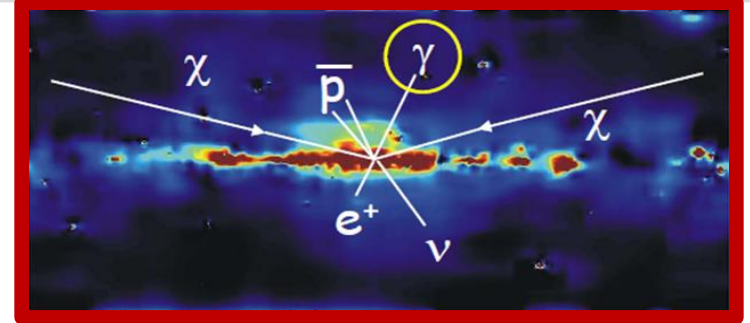
CTA-LST will cover **S.M.B.H., Dark Matter, AGNs, GRBs**



Cosmic Ray Origin



Super Massive Black Holes



Dark Matter Search (Discovery)

- Origin of Cosmic Rays (Big accelerators)
- Black Hole and S.M.B.H.
- Dark Matter Search

## Extragalactic Sources



Active Galactic Nuclei

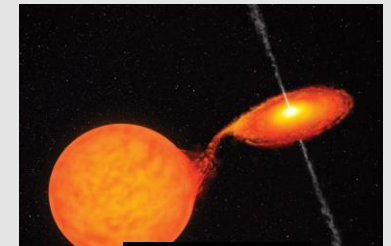


Gamma Ray Bursts

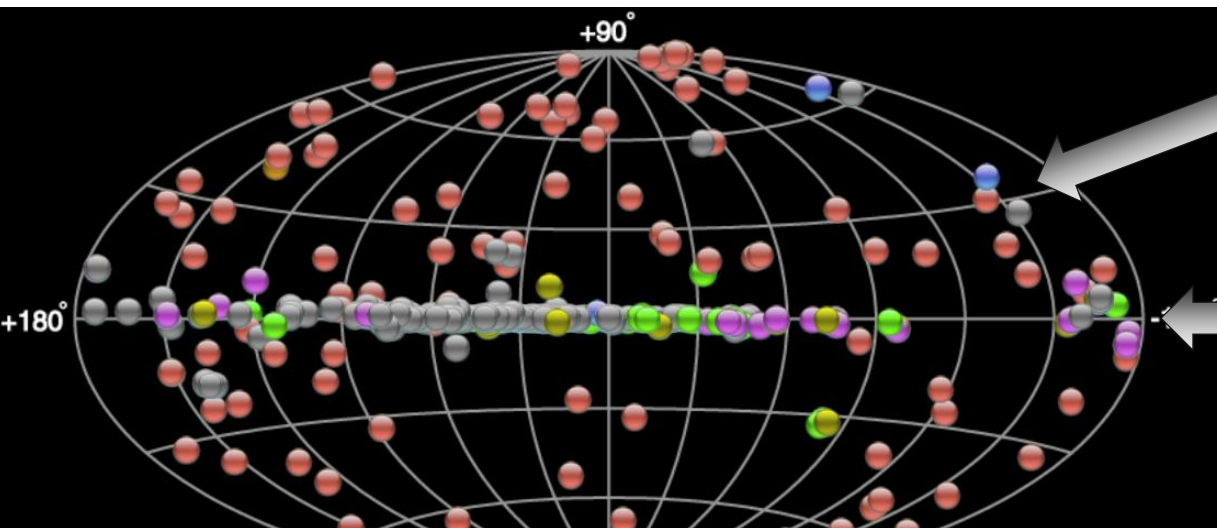
## Galactic Sources



Super Nova Remnants



Binaries



> 300 high energy sources are discovered.  
CTA will observe a few 1000 sources.

# LST Collaboration

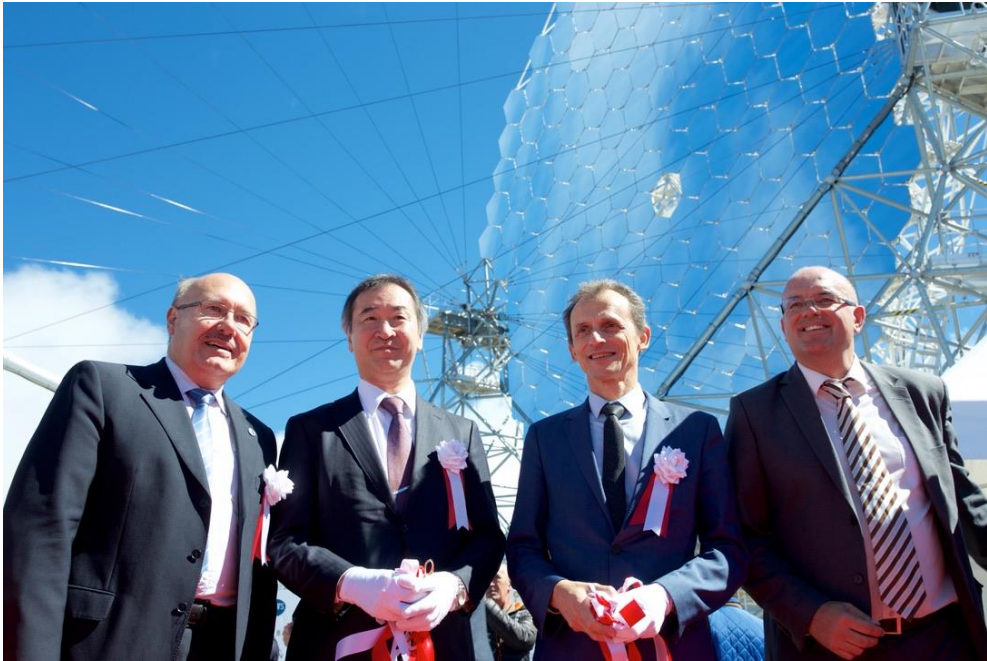
LST statistics			
	Members	Scientists + Students	Authors
Bulgaria	2	2	2
Brazil	3	2	2
Spain	92	61	56
France	42	21	21
Croatia	9	9	9
Czechia	19	19	12
Germany	49	42	39
Switzerland	22	19	16
Italy	129	103	78
Japan	87	82	65
Poland	5	5	5
<b>Total</b>	<b>459</b>	<b>365</b>	<b>305</b>



We have a good number of people



# LST1 was inaugurated in Oct.2018



# Large-Sized Telescope

Mirrors: JP  
Interface plates: JP, DE, BR  
Actuators: JP, CH, DE  
CMOS CAM: JP

calibration:  
IT, HR, IN, DE

Tension cables: IT

Camera Support  
Structure: FR

Camera electronics: JP, IT, ES, CH  
Camera mechanics: ES  
Camera safety: FR

Telescope  
structure: DE, ES

Rail: DE, ES

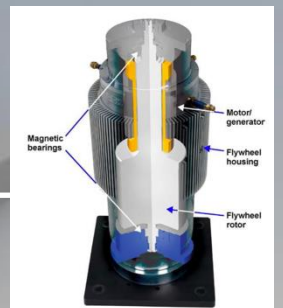
Camera Access Tower: DE, ES

Bogies: ES, DE

Foundation: ES

Drive and main  
el. cabinet: FR

FlyWheels (2x300kW)  
energy storage and UPS: JP



May 2024

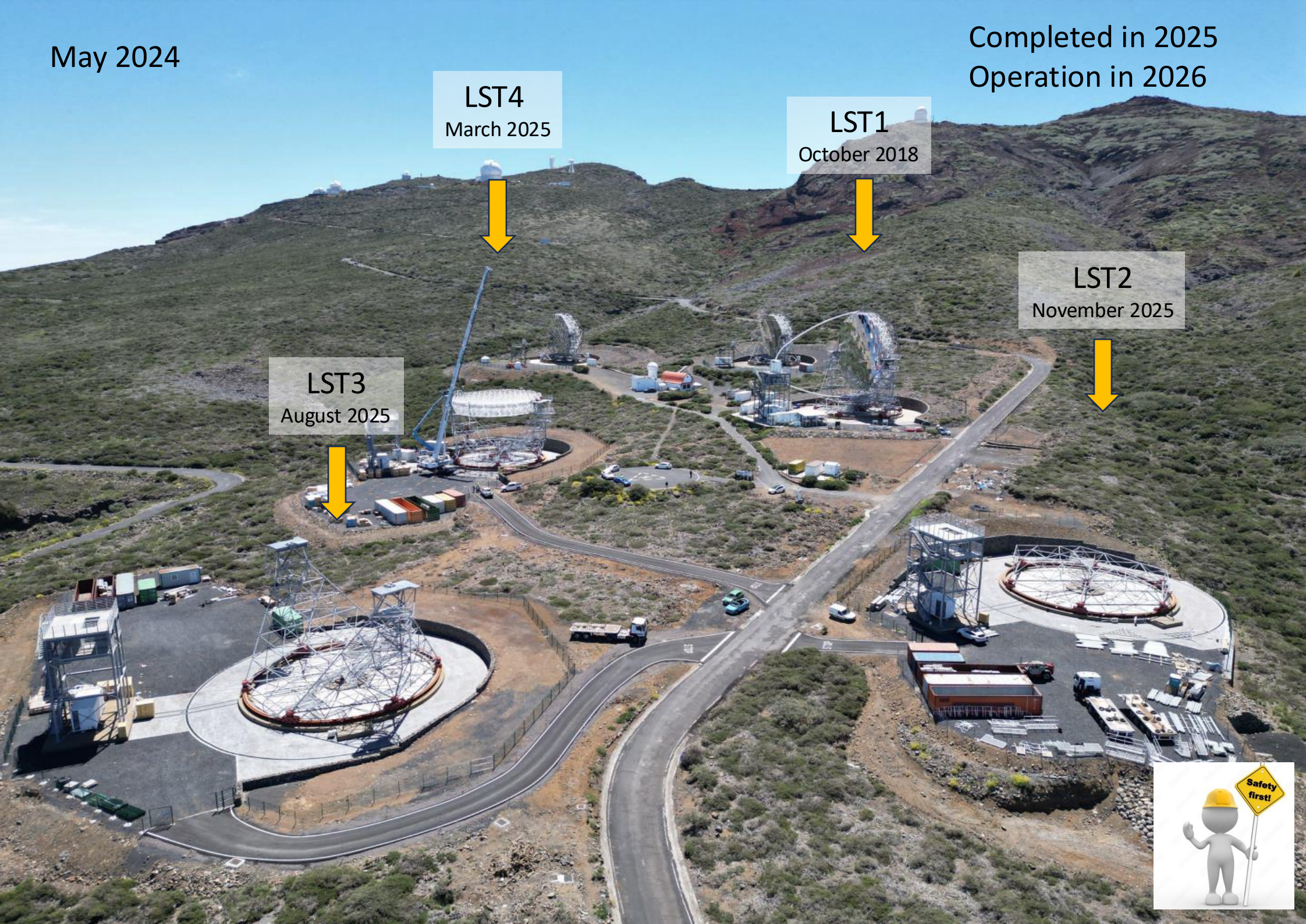
Completed in 2025  
Operation in 2026

LST4  
March 2025

LST1  
October 2018

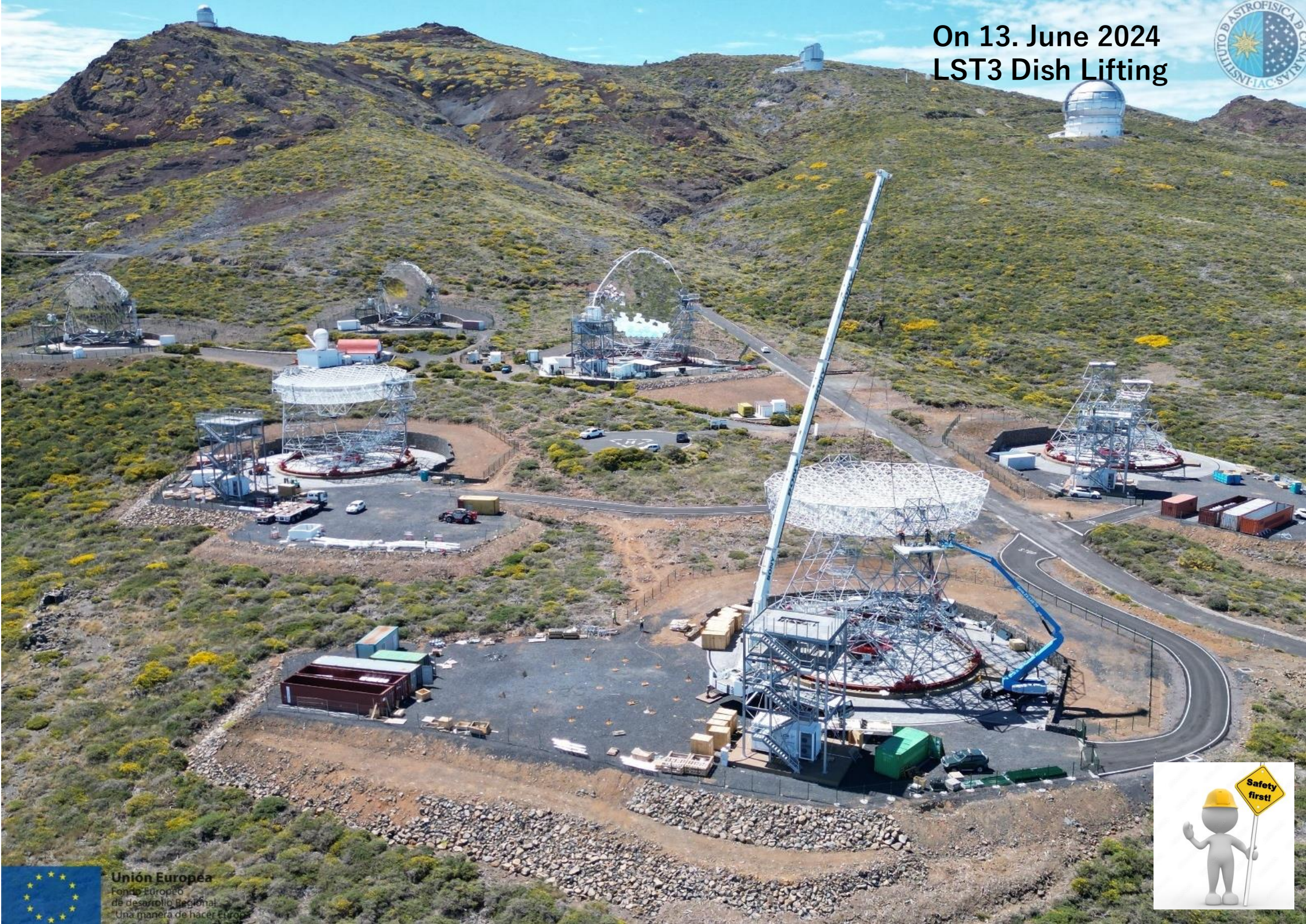
LST2  
November 2025

LST3  
August 2025





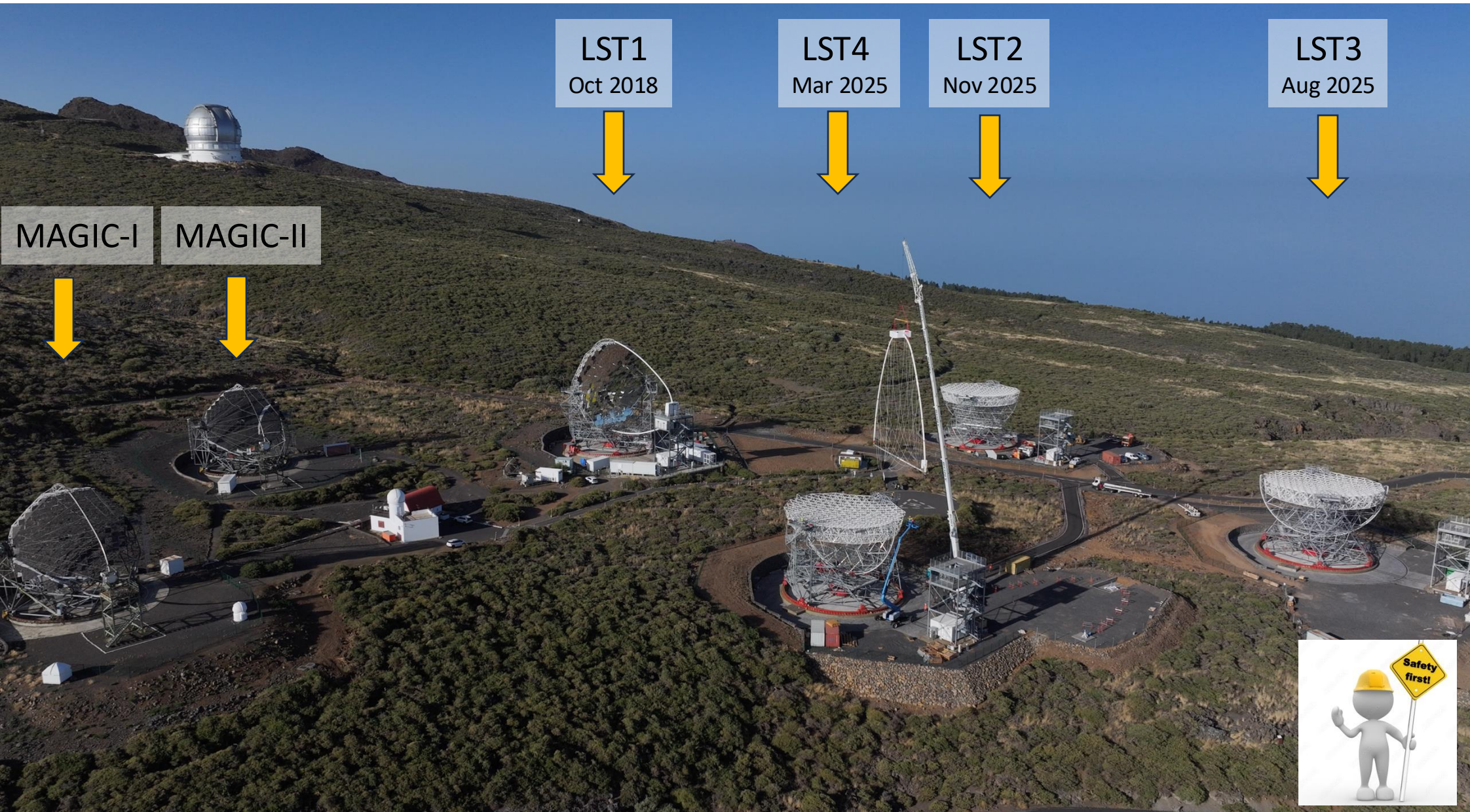
On 13. June 2024  
LST3 Dish Lifting



Unión Europea  
Fondo Europeo  
de desarrollo Regional  
Una manera de hacer Europa

# LST4 ARCH-CSS installation

on 22.Aug.2024



LST1  
Oct 2018

LST4  
Mar 2025

LST2  
Nov 2025

LST3  
Aug 2025

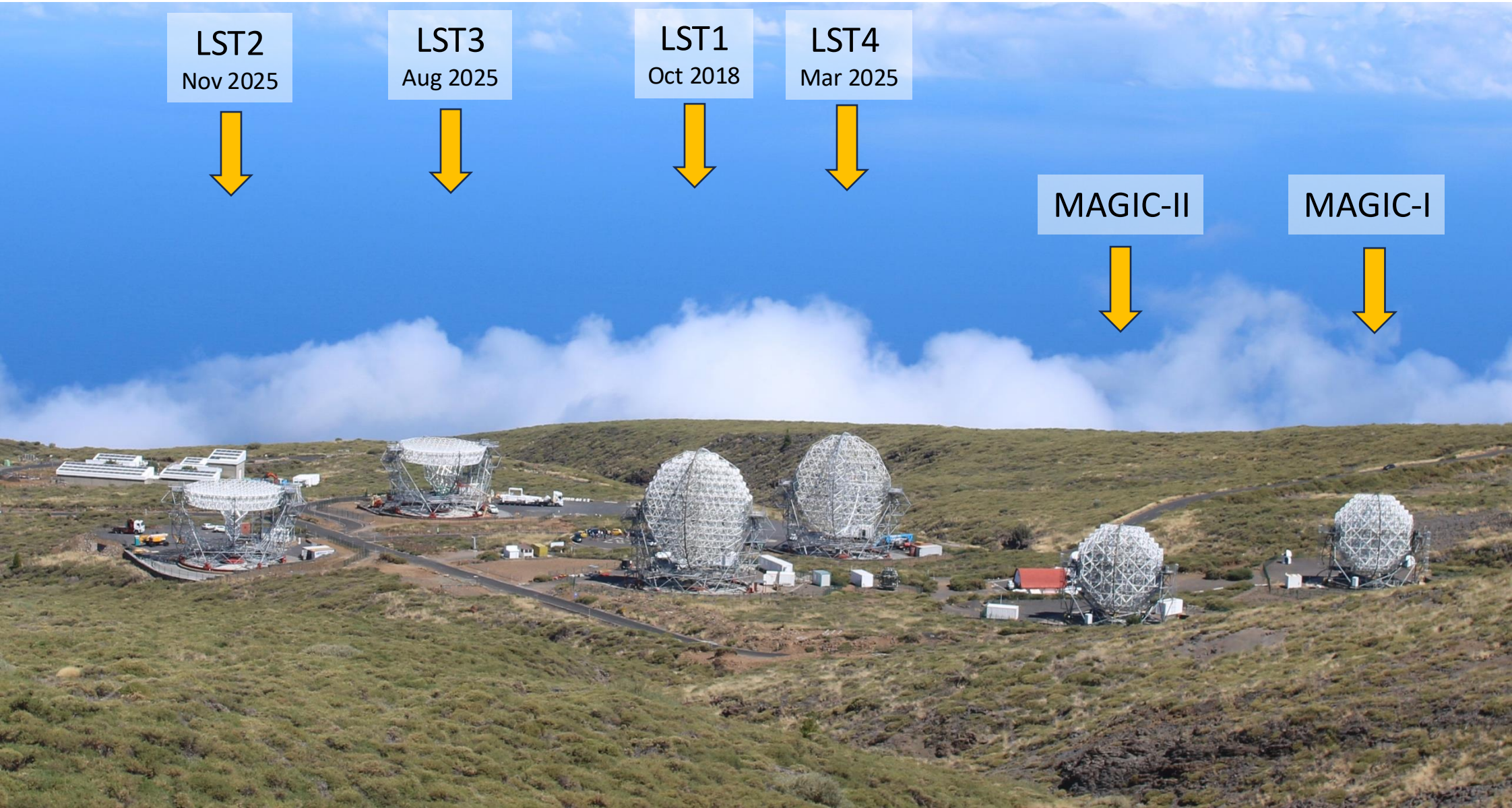
MAGIC-I

MAGIC-II



# CTAO North sites

on 30.Aug.2024



LST2  
Nov 2025



LST3  
Aug 2025



LST1  
Oct 2018



LST4  
Mar 2025



MAGIC-II

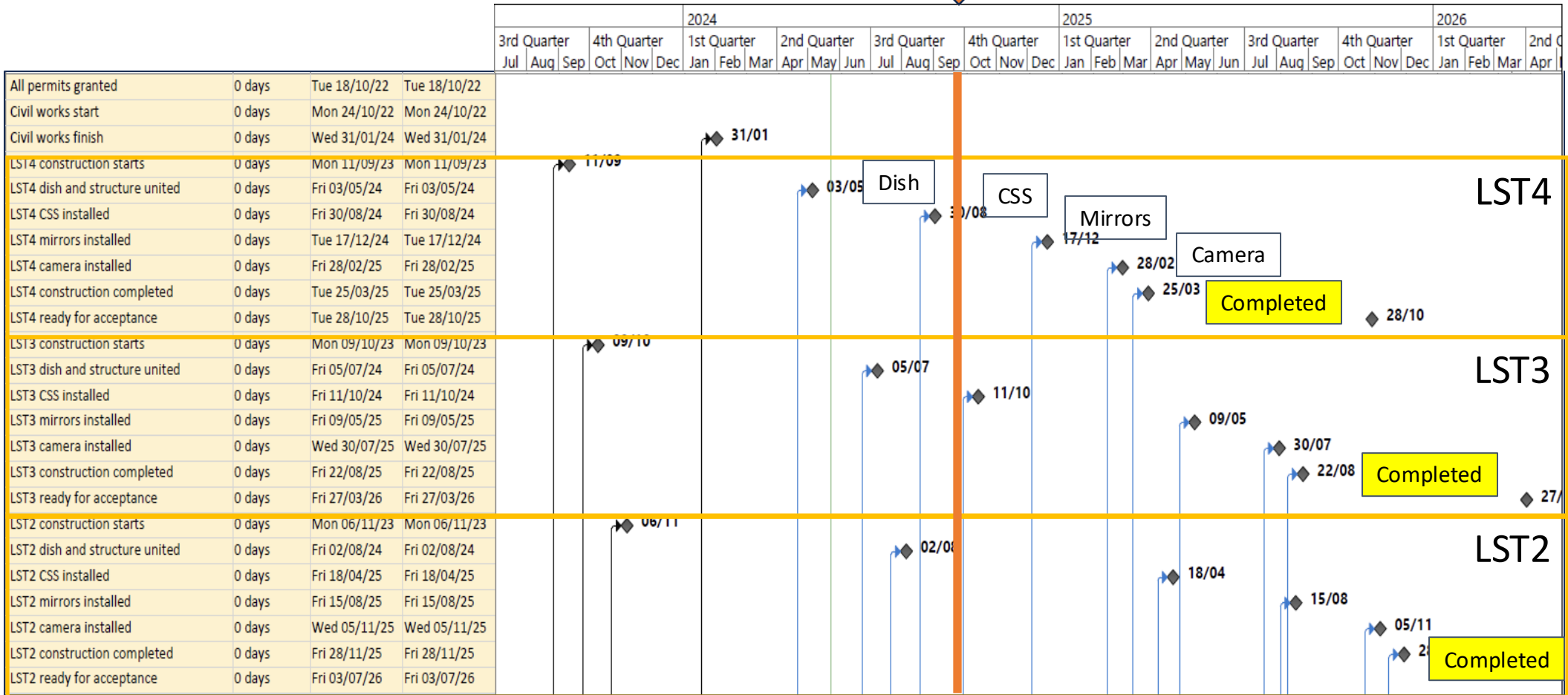


MAGIC-I



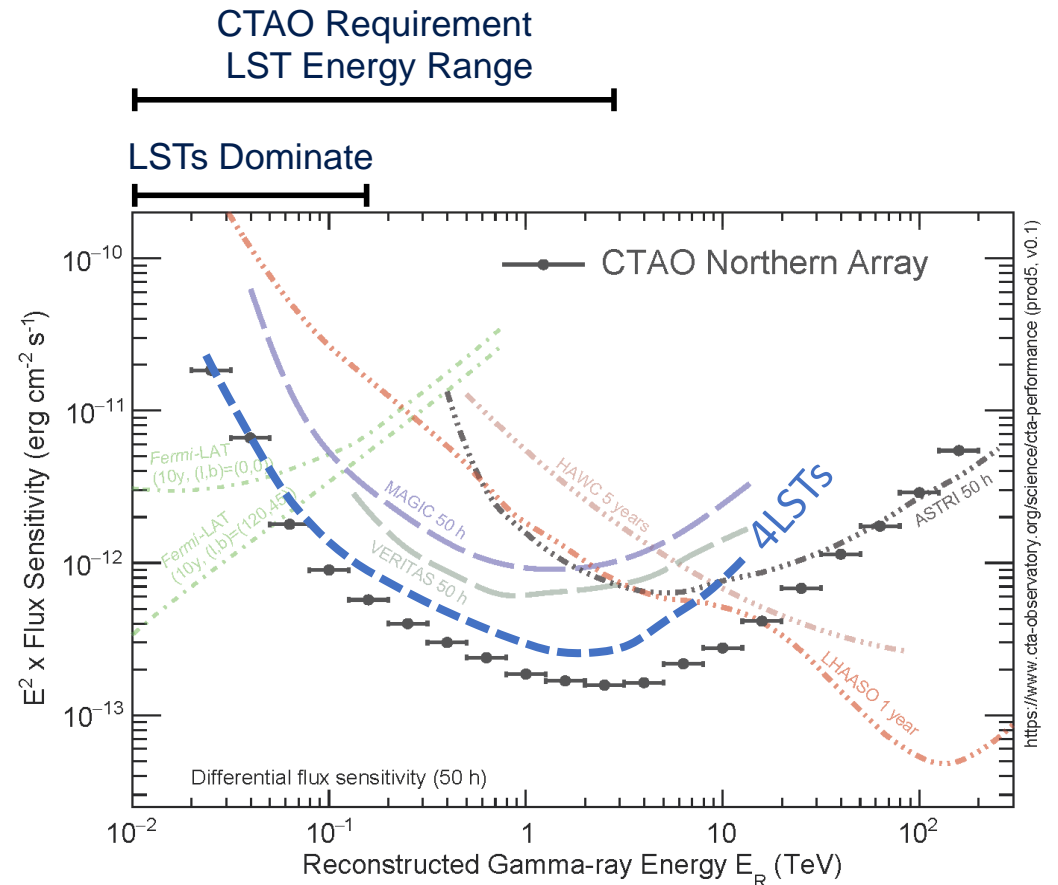
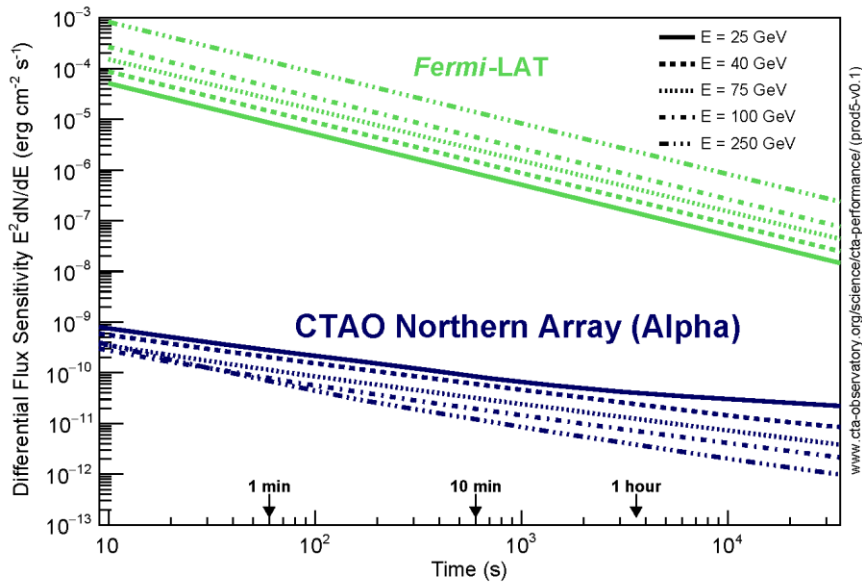
# Schedule for the LST2-4 construction

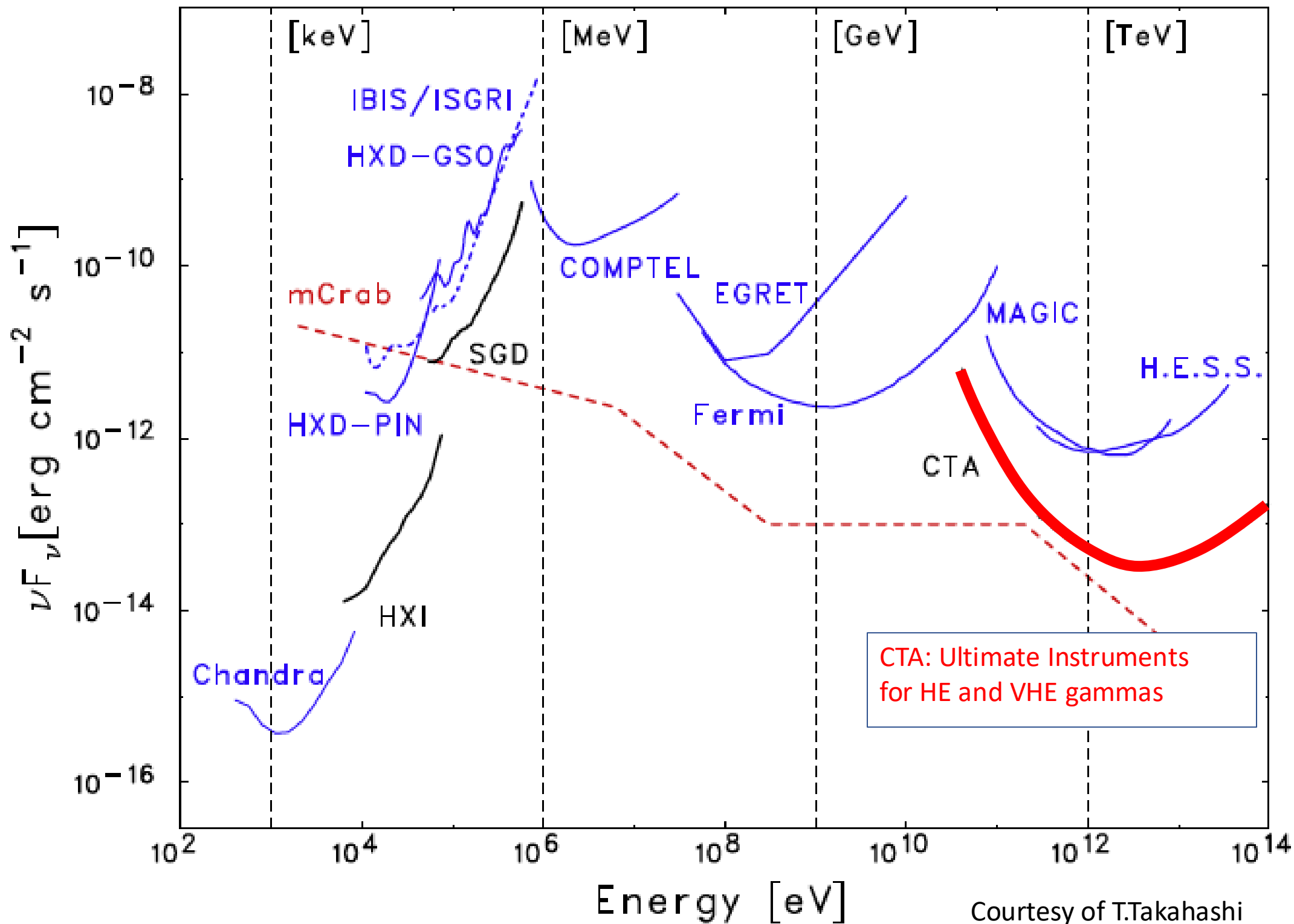
Now



# Performance of the CTAO North Array

- LSTs dominate CTAO sensitivity below 150 GeV
- Ideal for fast transients and soft sources

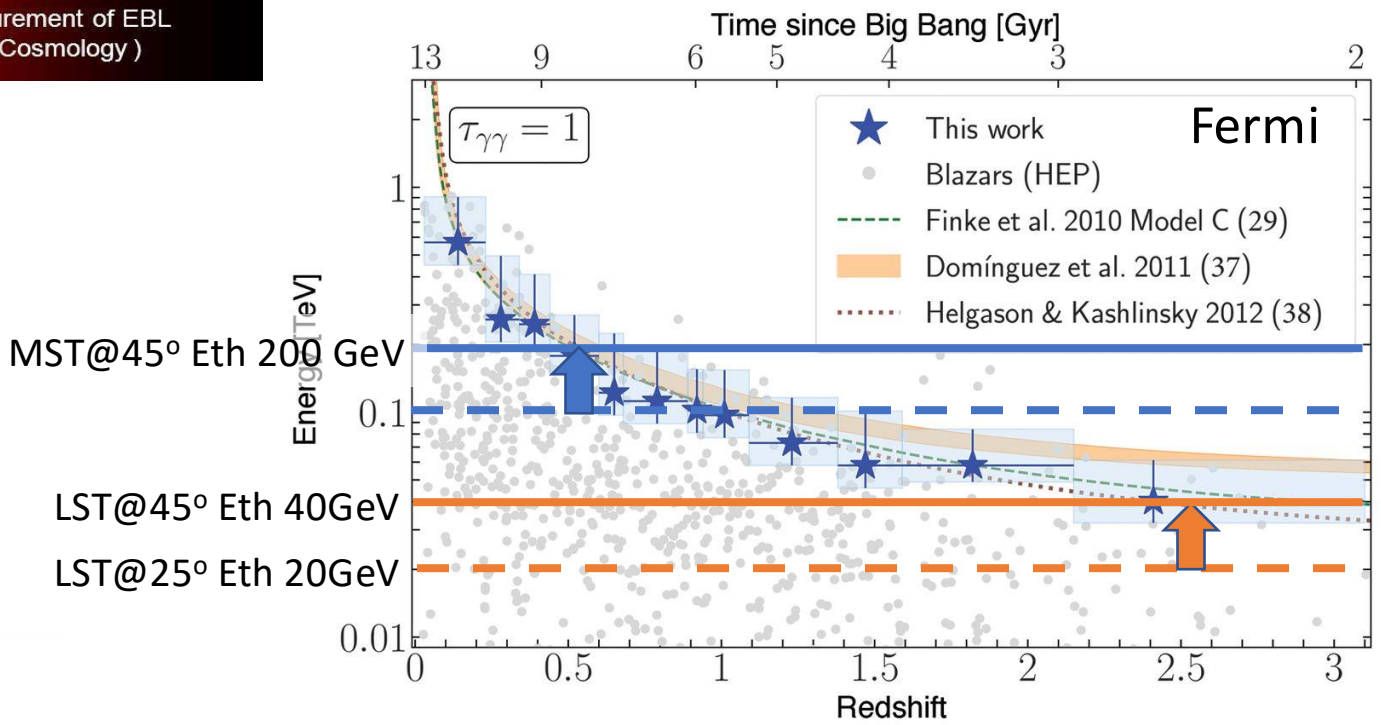
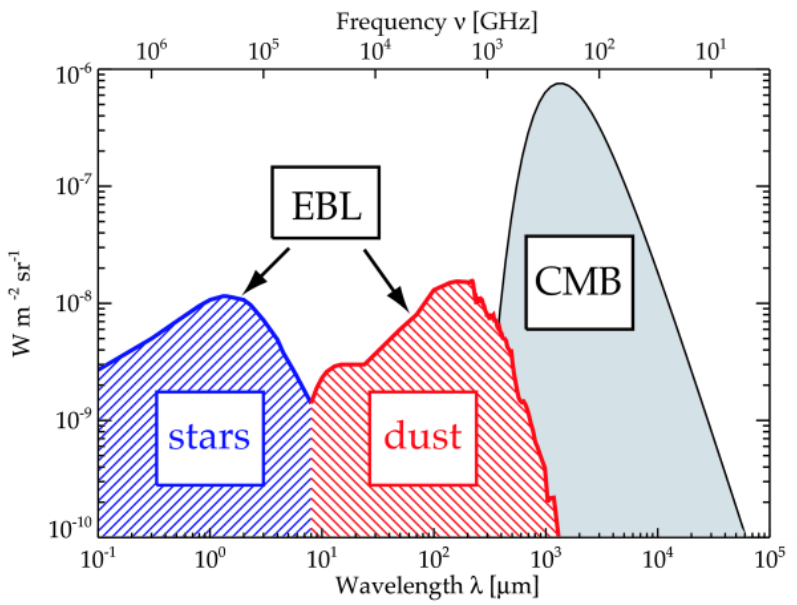
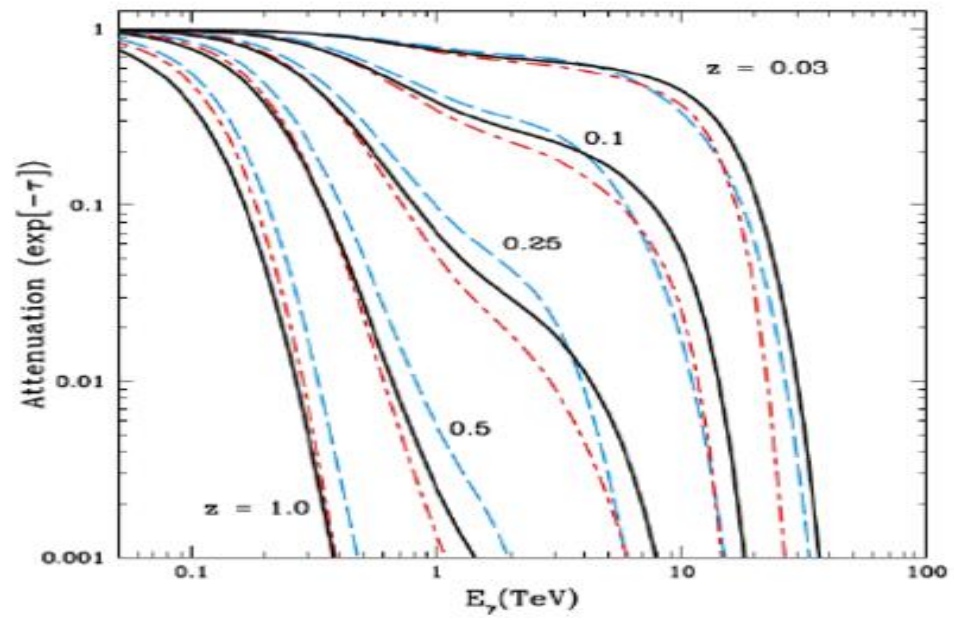
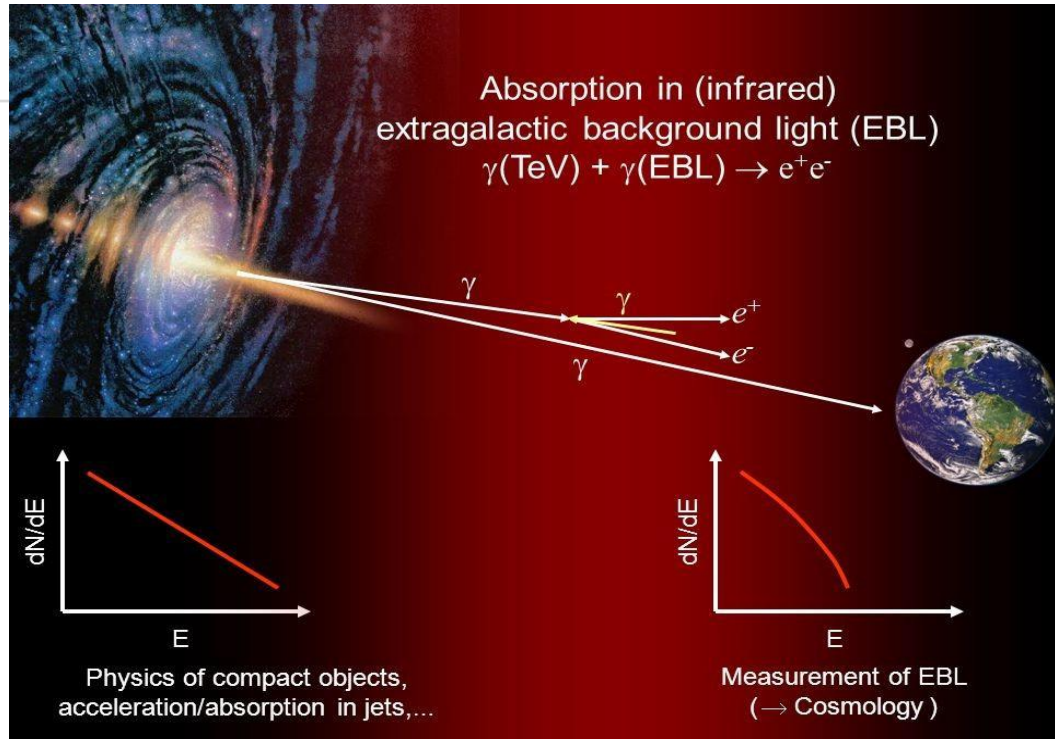




Courtesy of T.Takahashi

# Gamma Ray Horizon

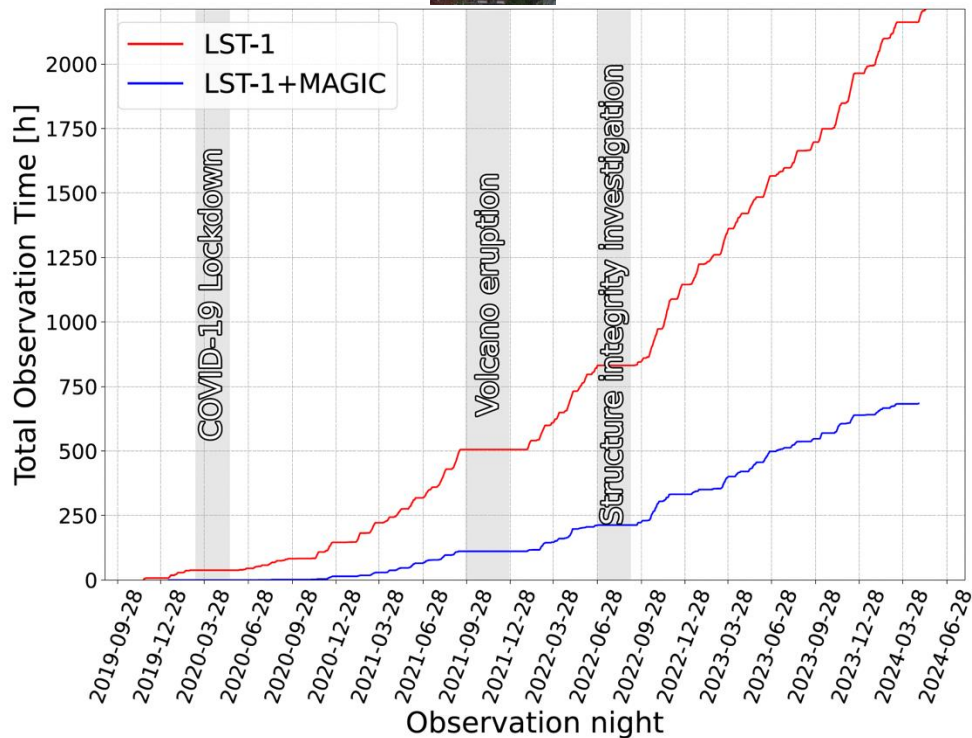
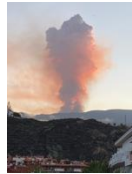
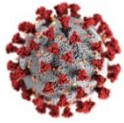
## Access the deep Universe with LSTs



# LST1 has been collecting data for more than 2000hrs

Oct 2018: LST1 Inaugurated  
Jan 2020: Scientific operation started

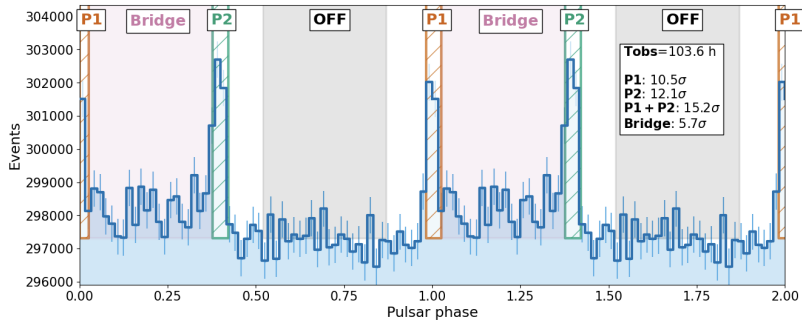
Quick follow-up observation with LST1 for GRBs and other transients.  
LST can point any sky direction in 20 seconds



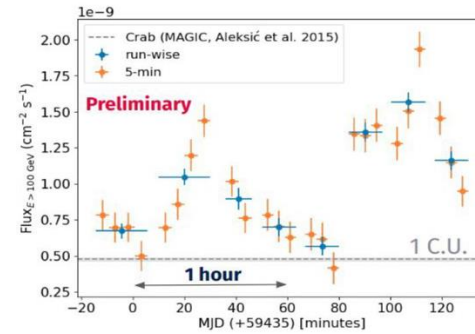


# Many scientific results are already delivered

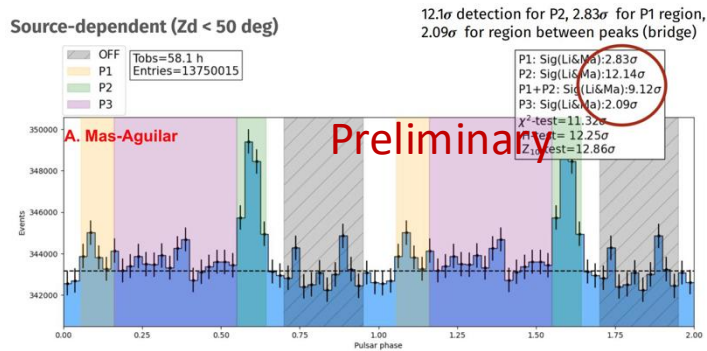
Crab pulsar above 20GeV



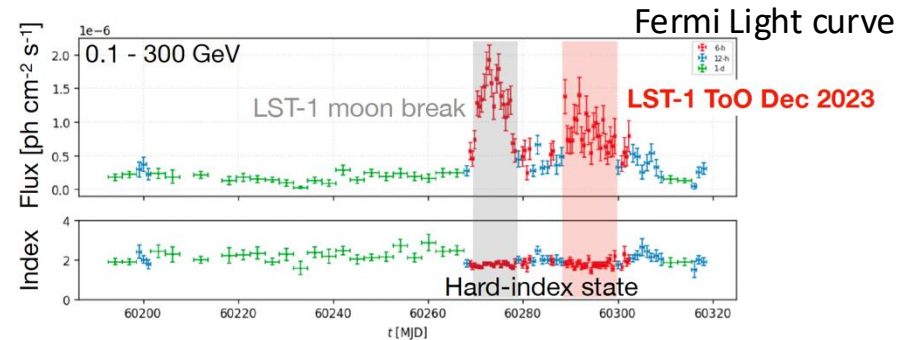
BL Lac intranight fast variability (a few min)



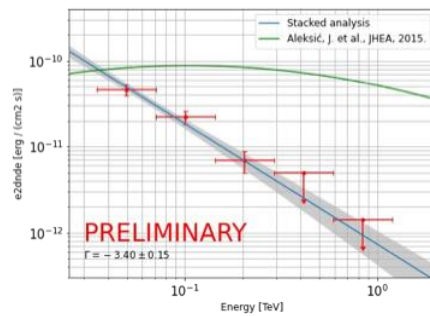
Geminga pulsar above 15GeV



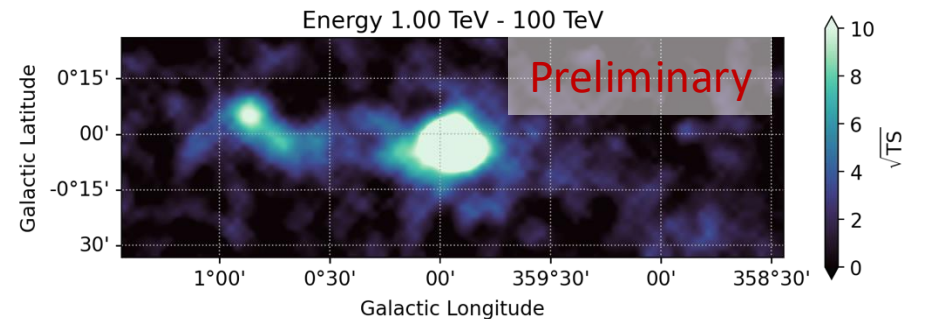
OP313: discovery of the most distant VHE AGN



Symbiotic Nova RS Ophiuchi

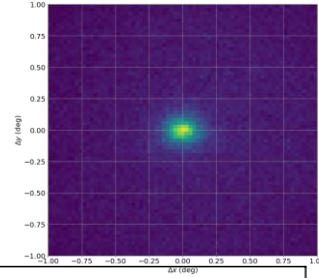


Galactic Center 39hrs (Sgr A\*, diffuse)



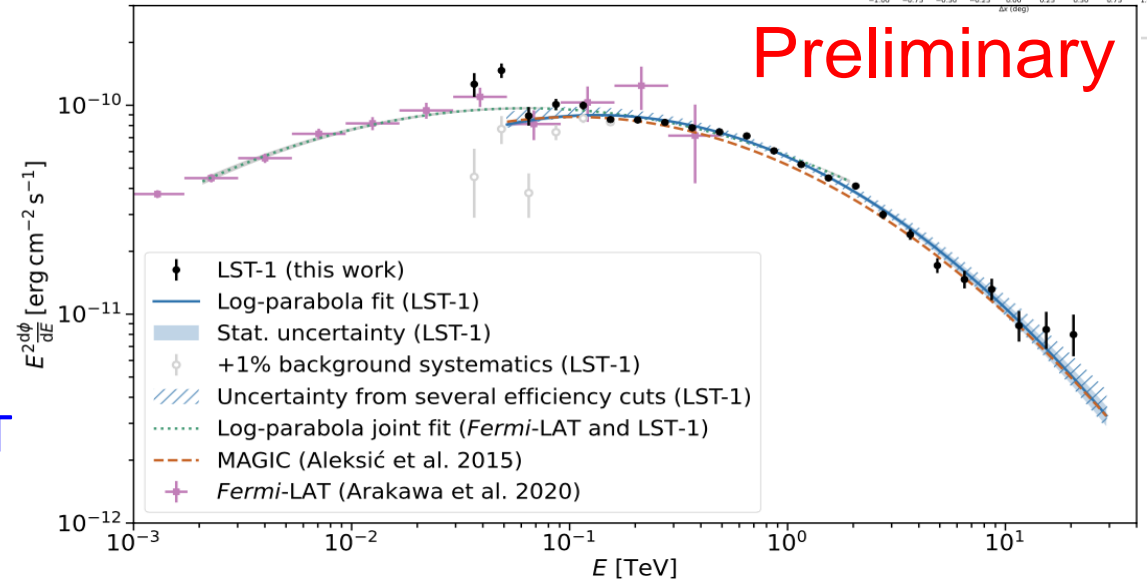


# Crab Nebula and Pulsar



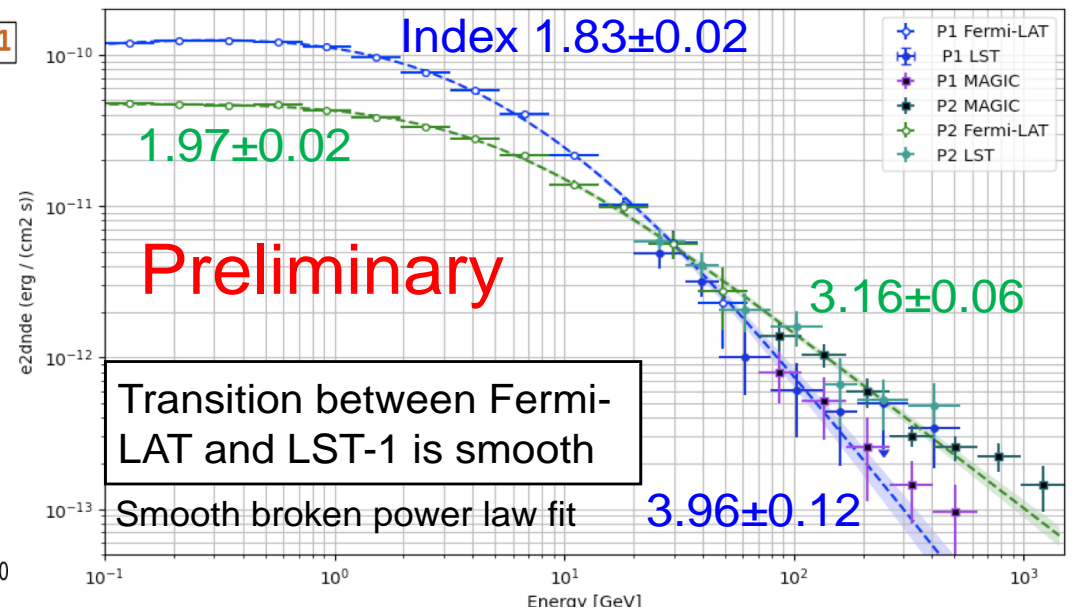
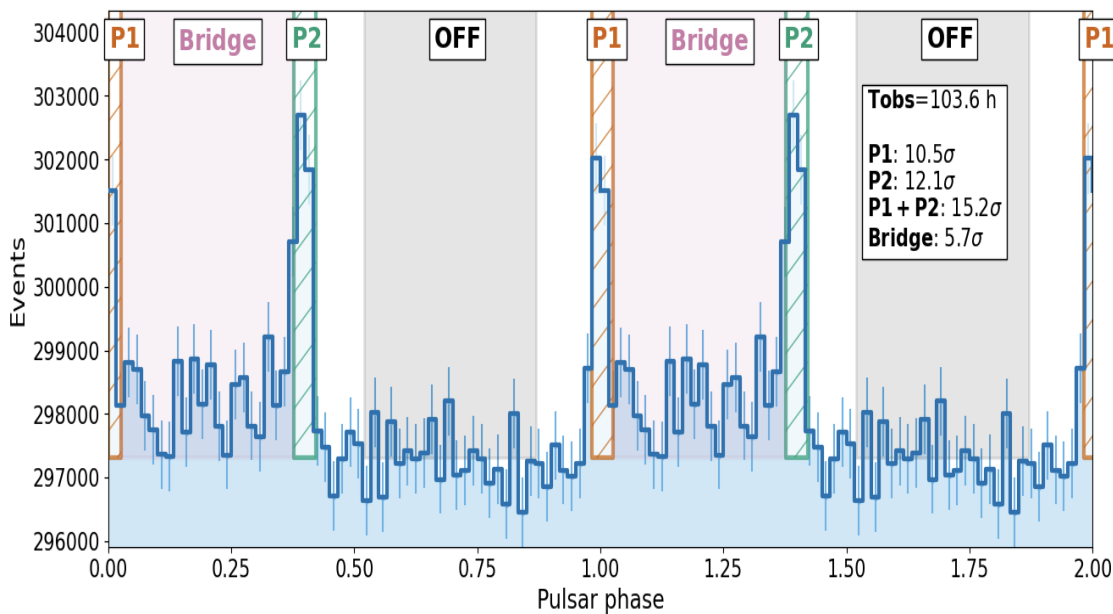
## Crab Nebula spectrum

- 34.2 hours of data
- Systematic errors: gray points correspond to the effect of +1% background
- Consistent with MAGIC and Fermi-LAT



## Crab pulsar

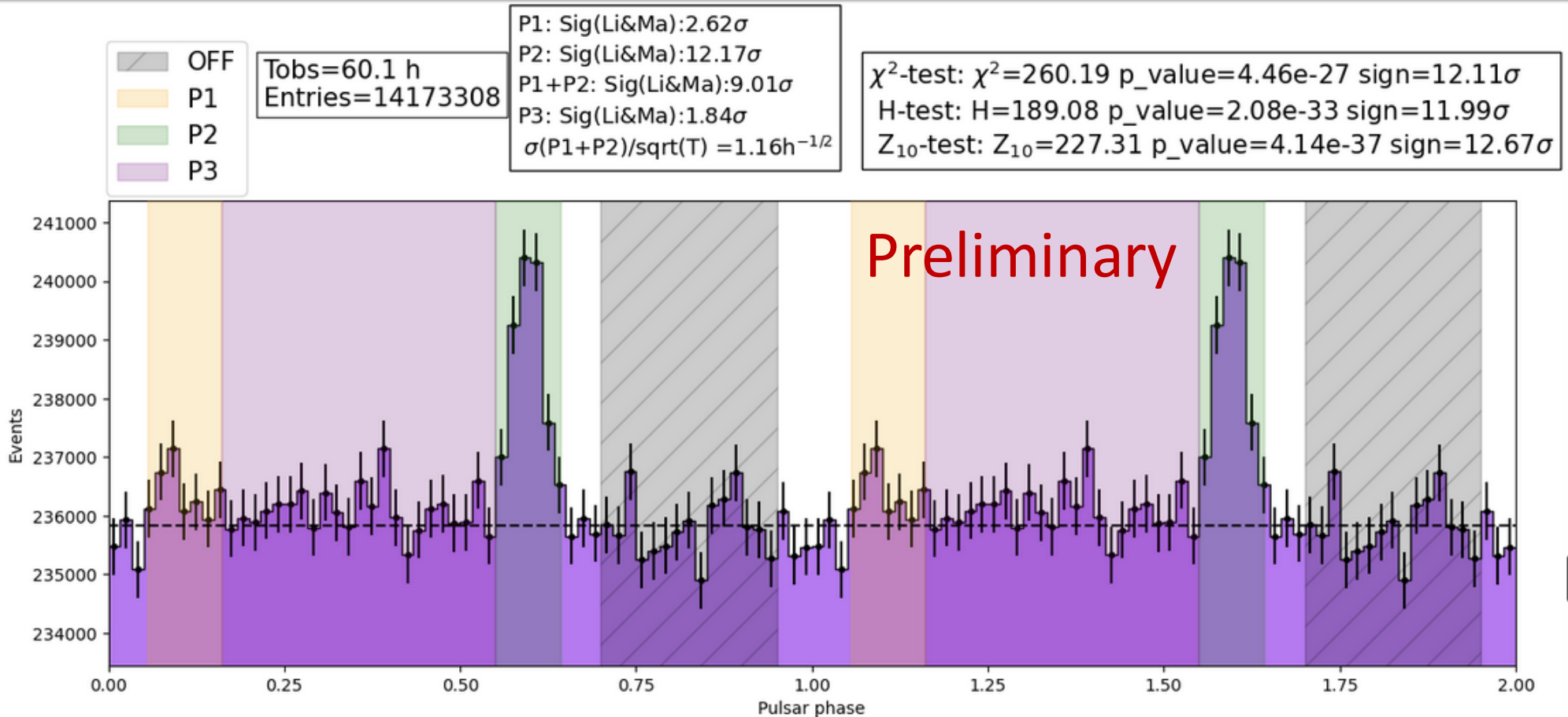
- Significant detection down to few tens of GeV



# Phase diagram from Geminga Pulsar with LST-1

12 sigma signal is observed with 60hrs observation  
 The energy threshold is estimated to be 15-20GeV

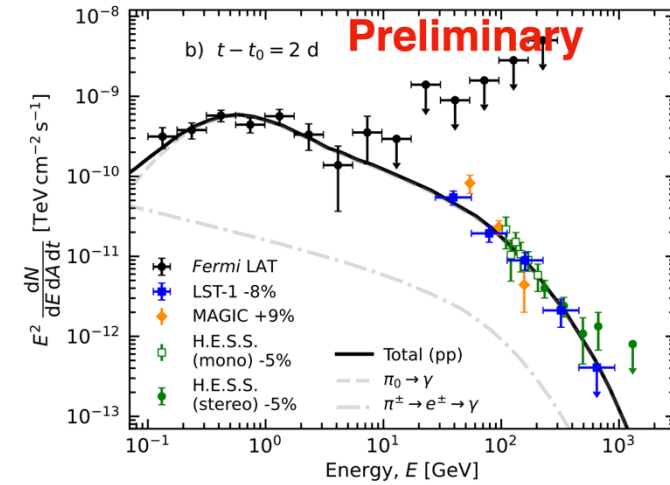
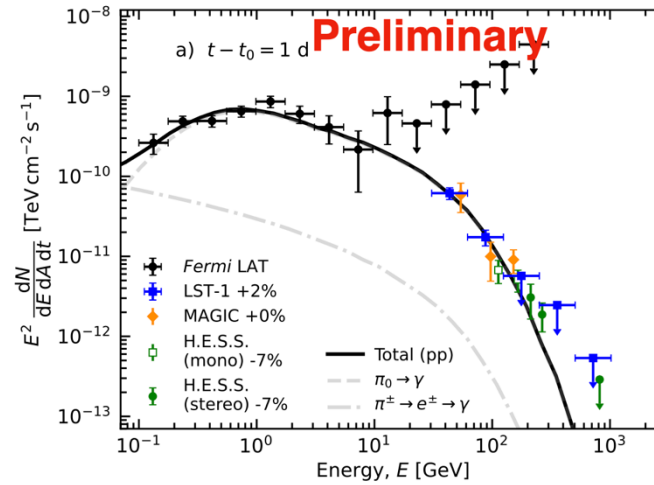
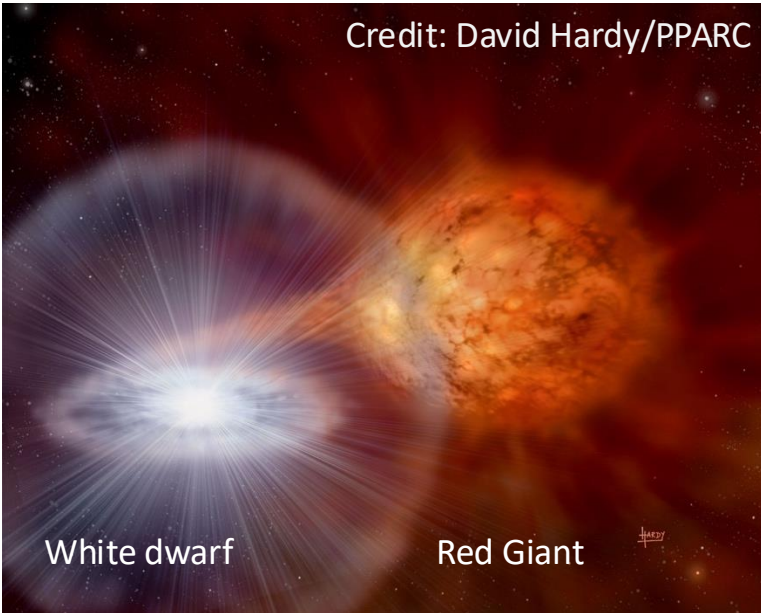
The results are almost ready for publication.



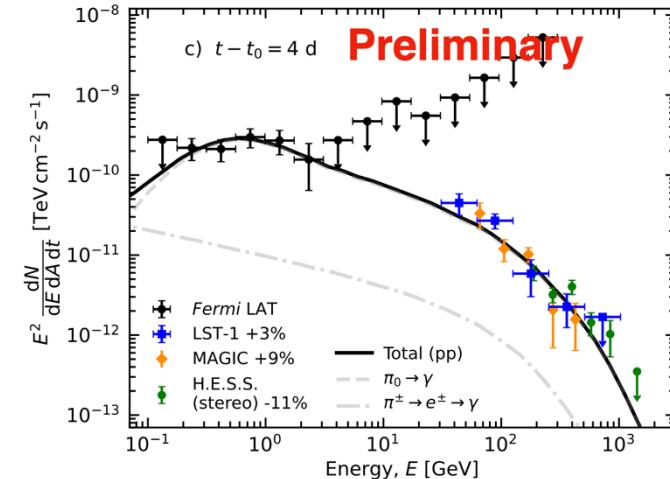
# RS Ophiuchi Outburst in August 2021: Evolution of the Energy Spectrum

- ❑ RS Ophiuchi is a recurrent Nova.
  - ❑ Explosions, 1898, 1933, 1958, 1985, 2006, **2021**
  - ❑ **Mag 12.5 (low state) → Mag 4.7 (~1000 times)**
  - ❑ Binary System with a White Dwarf and a Red Giant
  - ❑ Accumulation of material on the WD and then thermonuclear reaction make recurrent explosions

- ❑ The Hadronic model is preferred.
- ❑ Cutoff energy increased with time.

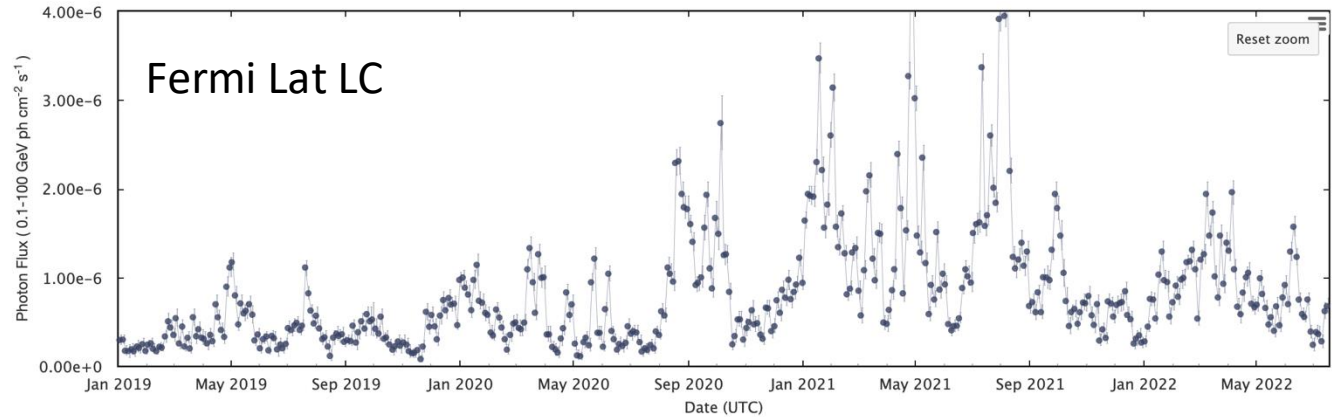


Parameter	Best-fit value on observation day		
	Day 1	Day 2	Day 4
<b>Preliminary</b>			
Hadronic ECPL model with systematics			
Slope, $\Gamma_p$	$-2.16^{+0.19}_{-0.18}$	$-2.49^{+0.05}_{-0.04}$	$-2.42^{+0.16}_{-0.16}$
$E_{c,p}$ [TeV]	$0.21^{+0.12}_{-0.11}$	$0.9^{+0.2}_{-0.2}$	$1.1^{+0.7}_{-0.7}$
LST-1 syst. [%]	$2^{+5}_{-5}$	$-8^{+8}_{-7}$	$3^{+6}_{-5}$
MAGIC syst. [%]	$0^{+7}_{-6}$	$9^{+6}_{-7}$	$9^{+6}_{-6}$
H.E.S.S. syst. [%]	$-7^{+9}_{-7}$	$-5^{+6}_{-5}$	$-11^{+4}_{-4}$
$\chi^2/N_{d.o.f}$	17.8/12	20.0/19	20.0/13
$\chi^2_{red}$	1.48	1.05	1.54
AIC	29.8	32.0	32.0

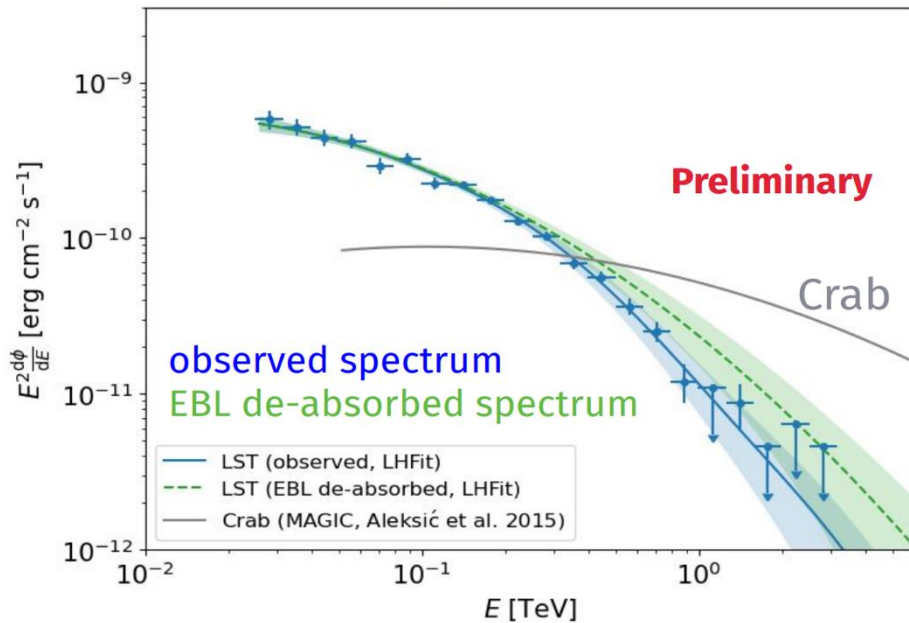


# BL Lac Flare 2021

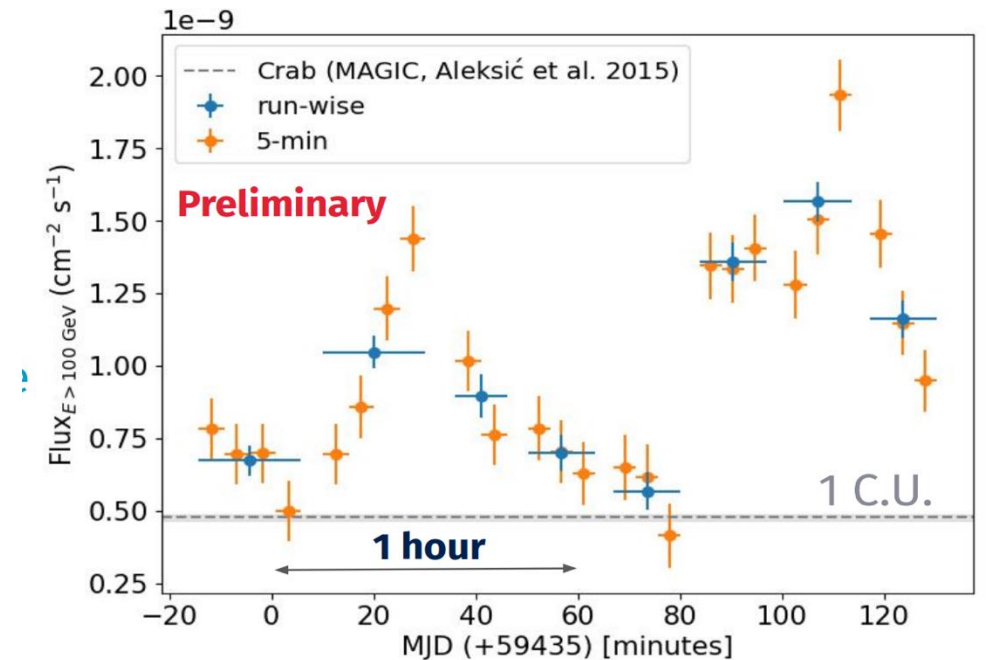
- ❑ BL Lac Flare 2021
- ❑ BL Lac: IBL,  $z = 0.069$
- ❑ Spectrum observed  $> 25\text{GeV}$
- ❑ August 9, about 3-5 Crab Unit at 30-100 GeV
- ❑ Very fast variability ( $< 5\text{min}$ )



Aug 9, 2021



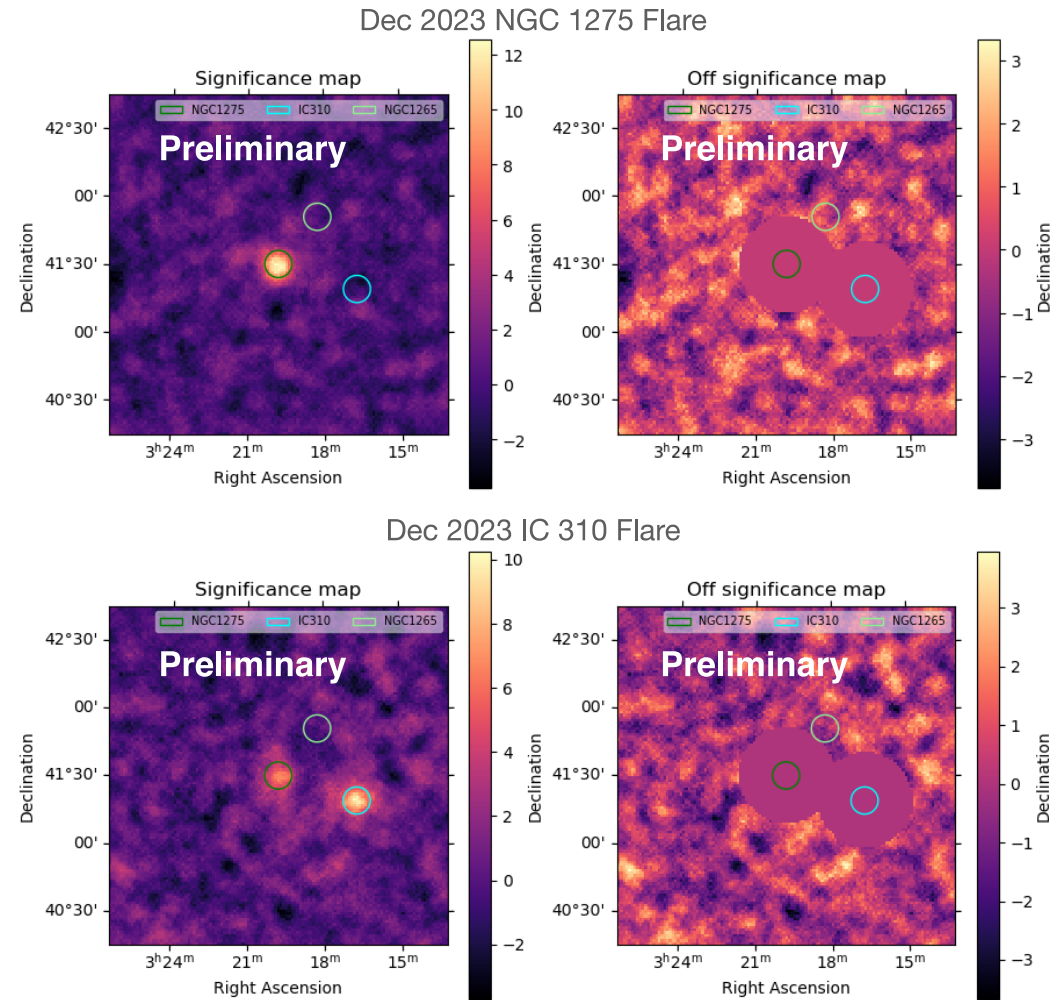
Intranight LC on 9 August, 5 min fast variability



# Perseus Cluster

## NGC1275 and IC310

- Cluster of radio galaxies in Perseus; ideal targets for LST: NGC 1275 and IC 310
- Timeline of Observations
  - NGC 1275 detected in Dec 2020, and then quiet afterwards
  - NGC 1275 began flaring again in December 2022 - January 2023
  - Again in December 2023, NGC 1275 and IC 310 began flaring together
  - While observing cluster, detected a single night flare of IC 310



# Discovery of OP313 ( $z = 0.997$ ) with LST-1

## First detection of VHE gamma-ray emission from FSRQ OP 313 with LST-1

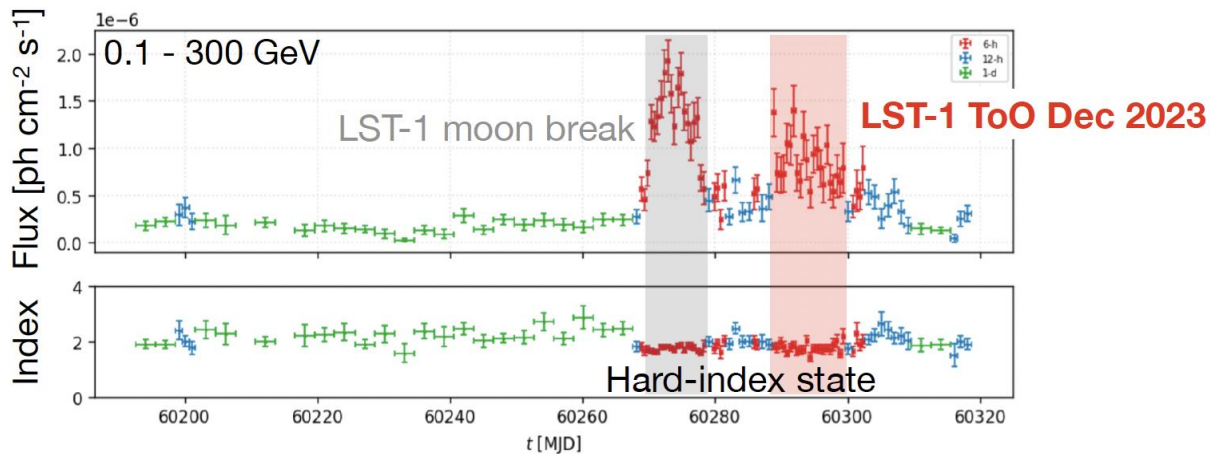
ATel #16381; *Juan Cortina (CIEMAT) for the CTAO LST collaboration*  
 on 15 Dec 2023; 14:31 UT

Credential Certification: *Juan Cortina (Juan.Cortina@ciemat.es)*

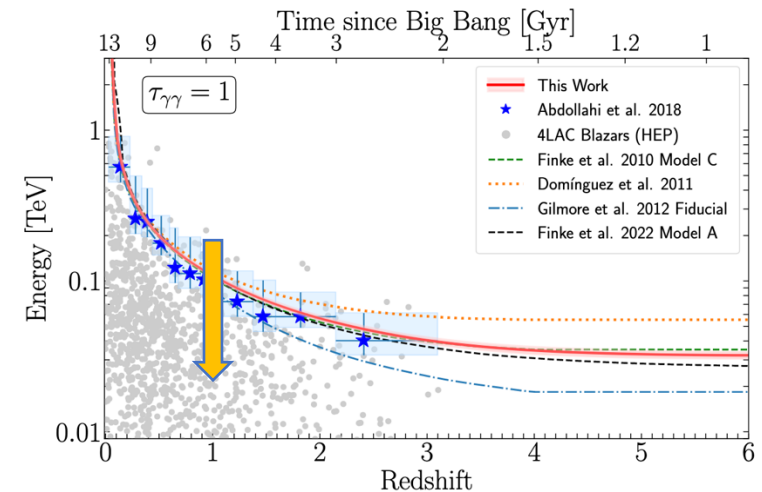
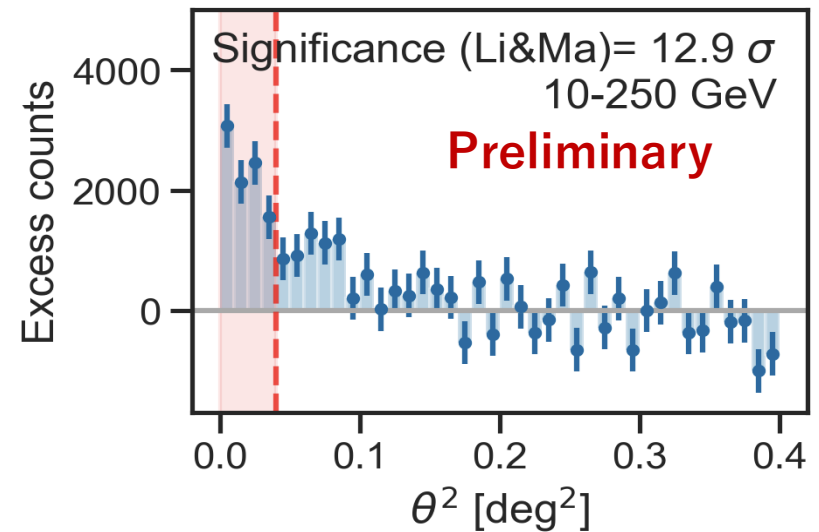
Subjects: Gamma Ray, >GeV, TeV, VHE, Request for Observations, AGN, Blazar, Quasar

**MAGIC, LST-1, and MAGIC+LST1 are analyzed. We are preparing the publication.**

Fermi Light Curve of OP313

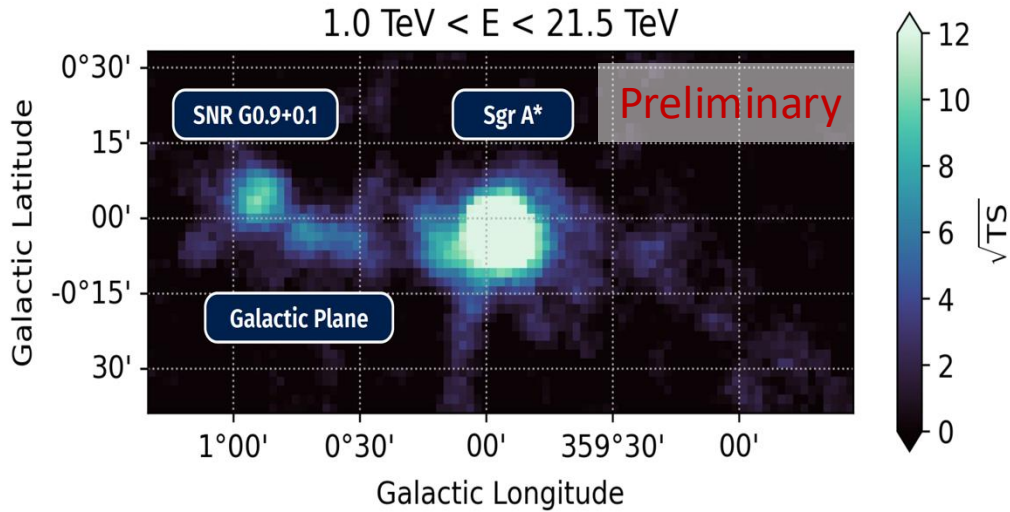


Stacking all December data 2023 data (14.6hrs)  
 13 sigma excess below 250GeV, No detection above 250GeV  
 Publication with detailed analysis is expected soon.



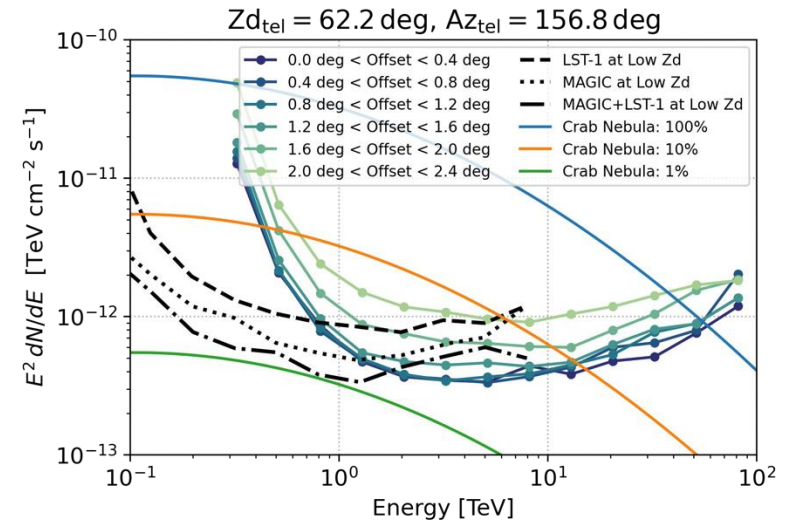
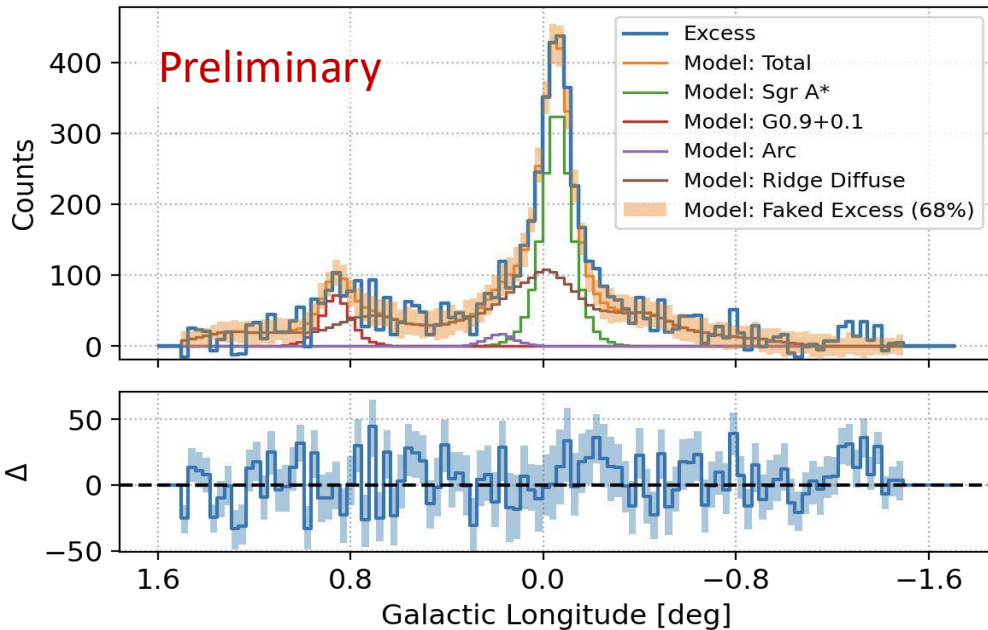
# Galactic Center region

- See the presentation by Shotaro Abe

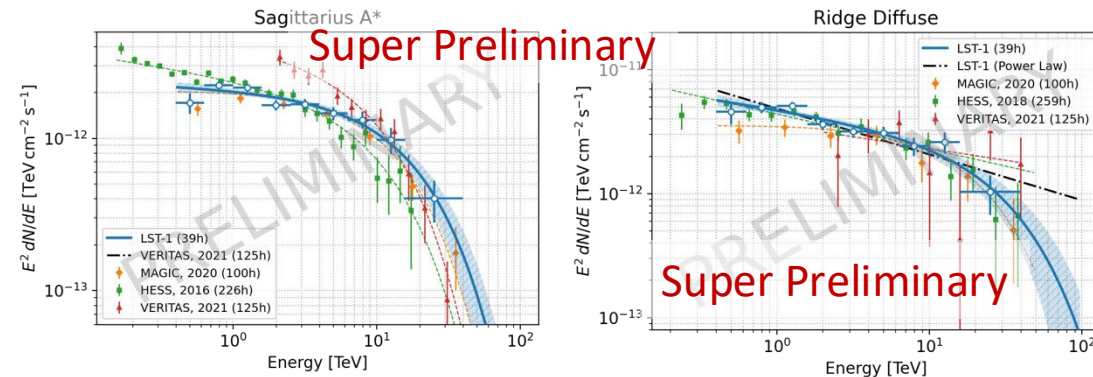


The galactic center is observed for 39hrs with the Large Zenith Angle Technique (ZD 58-68 deg).

Pros: Getting several times larger collection area  
 Cons: Higher Threshold Energy (> 300GeV)



Some trials to derive spectra from individuals





# Multi-messenger and Multi-wavelength Astrophysics

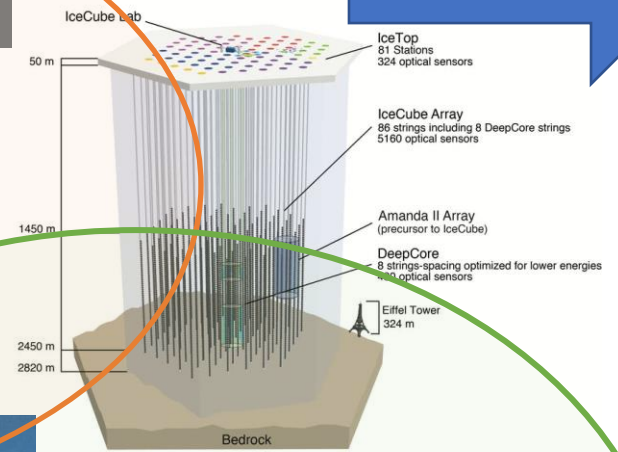
Wave  
AstroPhysics



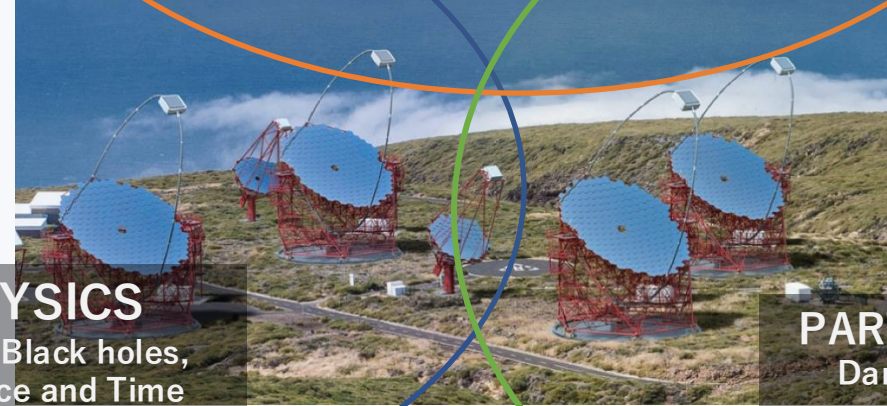
**ASTRO-PARTICLE PHYSICS**  
Cosmic Ray Physics  
High Energy Astrophysics



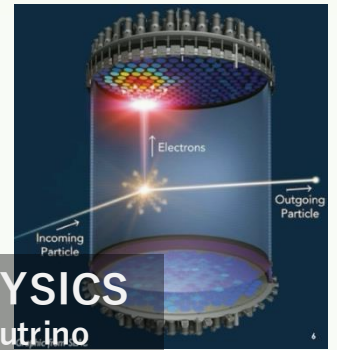
Particle Physics



**ASTRO-PHYSICS**  
Gamma Ray Bursts, Black holes,  
Neutron Stars, Space and Time



**PARTICLE PHYSICS**  
Dark Matter, Neutrino  
Energy Frontier



# Summary

- The first Large-Sized Telescope LST1 fulfills the requirement and the design performance, including **a fast follow-up capability of 20 sec.**
- LST2, LST3, and LST4 will be completed by the end of 2025, and then commissioning with four LSTs will start.
- The LST Array will achieve one order of magnitude higher sensitivity than currently running telescopes below 100 GeV and several times around 1TeV.
- The LST Array contributes to **the multi-messenger and time-domain astronomy.**

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**Stay Tuned!**



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**cherenkov  
telescope  
array**

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